Chapter 3. Ozone Related Benefits of Regional NOx Reductions

3.1 Results in Brief

In the Regulatory Impact Analysis for the Final Section 126 Petition Rule, we were unable to provide quantified or monetized benefit estimates for health and welfare effects associated with changes in ambient concentrations of ozone based on actual air quality modeling of ozone changes by the signature date for the rulemaking. Instead, to provide a more representative total benefits estimate for comparison with costs, we used a benefit transfer method to develop a projected estimate of ozone-related benefits for the final Section 126 rule. This chapter provides final estimates of ozone-related health and welfare benefits based on modeled air quality changes and a final estimate of total (ozone plus PM) quantified benefits. These benefits results are associated with Federally-imposed requirements in the May 25, 1999 Notice of Final Rulemaking (NFR) to reduce NOx emissions from sources contributing to downwind nonattainment of the ozone national ambient air quality standard (NAAQS). The benefits results presented in this chapter take into account the changes in the NOx emissions inventory made as a result of the inventory correction notices issued on January 13, 1999 and May 14, 1999, as well as the narrowed geographic scope and sources affected by the Section 126 remedy as a result of EPA's stay of the affirmative technical determinations based on the 8-hour ozone NAAQS.

Physical effects and monetary benefits are calculated for the selected Section 126 regulatory alternative (0.15 trading). Incremental ozone-related benefits (in 1997$) from implementation of the Section 126 NOx controls for the 2007 "Representative Year" SO_2 emissions banking scenario (holding sulfates constant between baseline and control air quality levels) are expected to be $0.2 billion. These estimates represent only the value of quantified health and welfare effects associated with changes in ozone. Total combined benefits (ozone and PM) are expected to $1.2 billion. A summary of the total benefits is presented in Chapter 4, along with a comparison of costs and benefits.

The largest monetized ozone-related benefit is associated with increases in outdoor worker productivity associated with reductions in ozone exposure. Other significant effects include reductions in chronic asthma and minor respiratory illnesses and increases in agricultural yields. The final Section 126 rule also results in decreases in hospitalizations for respiratory and cardiovascular illnesses and asthma related emergency room visits.

This benefits analysis does not quantify all potential benefits or disbenefits associated with changes in ambient ozone concentrations. The magnitude of the unquantified benefits associated with omitted categories, such as damage to ecosystems, is not known. However, to the extent that unquantified benefits exceed unquantified disbenefits, the estimated benefits presented above will be an underestimate of actual benefits. The methods for estimating monetized benefits for the final Section 126 rule and a more detailed analysis of the results are presented below.

3.2 Introduction

This chapter reports EPA's analysis of the economic benefits of changes in ambient ozone concentrations resulting from the final Section 126 rule. EPA is required by Executive Order 12866 to estimate the benefits of new pollution control regulations. The analysis presented here attempts to answer two questions: 1) what are the physical effects of changes in ambient ozone concentrations resulting from reduction in NOx emissions?; and 2) how much are the changes in ozone concentrations worth to U.S. citizens as a whole in monetary terms? It constitutes one part of EPA's thorough examination of all aspects of the relative merits of regulatory alternatives.

As mentioned previously, this chapter provides benefits results associated with Federally-imposed requirements in the May 25, 1999 Notice of Final Rulemaking (NFR) to reduce NOx emissions from sources contributing to downwind nonattainment of the ozone national ambient air quality standard (NAAQS). The benefits results presented in this chapter take into account the changes in the NOx emissions inventory made as a result of the inventory correction notices issued on January 13, 1999 and May 14, 1999, as well as the narrowed geographic scope and sources affected by the Section 126 remedy as a result of EPA's stay of the findings based on the 8-hour ozone NAAQS.

The changes in emissions resulting from the implementation of Section 126 controls have been described in Chapter 9 of the Regulatory Impact Analysis for the Final Section 126 Petition Rule (the Section 126 RIA). These changes in turn are expected to bring about different levels of ambient ozone concentrations over time and space, which have been modeled and are described in Chapter 2 of this supplementary volume. Changes in ambient ozone concentrations will lead to new levels of environmental quality in the US, reflected both in human health and in non-health welfare effects. In Chapters 9 and 11 of the Section 126 RIA, several scenarios related to the banking of SO2 emission credits were described. The analysis of ozone benefits is not affected by how SO2 banking is modeled. However, in the aggregation of ozone and PM benefits, we use the "representative year" SO2 banking scenario. As described in Chapters 9 and 11 of the Section 126 RIA, EPA believes that the "representative year" SO_2 banking scenario is a closer approximation to the expected annual benefits of the final Section 126 rule, and will thus be the only scenario that is carried over into the comparison of benefits and costs.

EPA has used the best available information and tools of analysis to quantify the expected changes in public health and the environment and to monetize the economic benefits of the final Section 126 rule, given the constraints on time and resources available for the analysis. We have attempted to be as clear as possible in presenting our assumptions, sources of data, and sources of potential uncertainty in the analysis. We urge the reader to pay particular attention to the fact that not all the benefits of the rule can be estimated with sufficient reliability to be quantified and valued in monetary terms. The omission of these items from the total of monetary benefits reflects our inability to measure

them. It does not indicate their lack of importance in the consideration of the benefits of this rulemaking.

We were unable to provide quantified or monetized benefit estimates for health and welfare effects associated with ambient concentrations of ozone based on actual air quality modeling of ozone changes by the signature date for this rulemaking. Instead, to provide a more representative total benefits estimate for comparison with costs, we used a benefit transfer method to develop a projected estimate of ozone-related benefits for the final Section 126 rule. A description of the benefit transfer method and the projected estimate of ozone-related benefits is presented in Chapter 12 of the Section 126 RIA. This supplementary volume provides final estimates of ozone-related health and welfare benefits based on modeled air quality changes and final estimate of total (ozone plus PM) quantified benefits and net benefits.

Although we were unable to provide quantitative estimates of ozone-related health and welfare benefits in the Section 126 RIA, we provided a complete discussion of the health effects and methods for quantifying and monetizing those effects. These can be found in Chapter 11 of the Section 126 RIA, along with a more complete discussion of the benefits analysis methodology and the uncertainties and limitations of the analysis. Additional information about specific quantification or valuation methods can be found in the technical support document accompanying the RIA (Abt Associates, 1999). Table 3-1. lists the ozone-related health and welfare effects considered in this supplementary benefits analysis[1]. The final section (Section 3.3) of this chapter consists of the results of the analysis of ozone-related human health and welfare benefits listed in Table 3-1.

[1] In the benefits analysis for the Section 126 Proposal/Final NOx SIP Call RIA, we also estimated reductions in the incidence of premature mortality associated with reduced exposures to ozone. At least some evidence has been found linking both PM and ozone with premature mortality. The SAB has raised concerns that mortality-related benefits of air pollution reductions may be overstated if separate pollutant-specific estimates, some of which may have been obtained from models excluding the other pollutants, are aggregated. In addition, there may be important interactions between pollutants and their effect on mortality (EPA-SAB-Council-ADV-99-012, 1999)

The Pope et al. (1995) study used to quantify PM-related mortality included only PM, so it is unclear to what extent it may include the impacts of ozone or other gaseous pollutants. Because of concern about overstating of benefits and because the evidence associating mortality with exposure to particulate matter is currently stronger than for ozone, only the benefits of PM-related premature mortality avoided are included in the total benefits estimate. The benefits associated with ozone reductions are presented as a sensitivity analysis in Appendix A but are not included in the estimate of total benefits.

Table 3-1.
Human Health and Welfare Effects of Ambient Ozone

	Primary Quantified and Monetized Effects	Unquantified Effects
Health	Chronic asthma[a] Minor restricted activity days and acute respiratory symptoms Hospital admissions - respiratory and cardiovascular Emergency room visits for asthma	Premature mortality[b] Increased airway responsiveness to stimuli Inflammation in the lung Chronic respiratory damage Premature aging of the lungs Acute inflammation and respiratory cell damage Increased susceptibility to respiratory infection Non-asthma respiratory emergency room visits Reduction in screening of UV-b radiation
Welfare	Decreased worker productivity Decreased yields for commercial crops	Decreased yields for commercial forests Decreased yields for fruits and vegetables Decreased yields for non-commercial crops Damage to urban ornamental plants Impacts on recreational demand from damaged forest aesthetics Damage to ecosystem functions

[a] While no causal mechanism has been identified linking new incidences of chronic asthma to ozone exposure, a recent epidemiological study shows a statistical association between long-term exposure to ozone and incidences of chronic asthma in some non-smoking men, but not in wormen.

[b] Premature mortality associated with ozone is not separately included in this analysis. It is assumed that the Pope, et al. C-R function for premature mortality captures both PM mortality benefits and any mortality benefits associated with other air pollutants (see Chapter 11 of the Section 126 RIA for a more complete discussion of measurement and valuation of air pollution related mortality.)

3.3 Estimated Reductions in Ozone-related Health and Welfare Effects and Associated Monetary Values

Tables 3-2 and 3-3 summarize the studies used to quantify the changes in health and welfare effects resulting from changes in ozone. Applying the C-R and valuation functions described in these tables to the estimated changes in ozone in 2007 (described in Chapter 2) yields estimates of the number of avoided incidences (i.e., cases, hospital admissions, etc.) and the associated monetary values for those avoided incidences. These estimates are presented in Table 3-4. All of the monetary benefits are in constant 1997 dollars.

We are unable to provide quantified or monetized estimates for many known health and welfare benefits associated with reductions in ozone. Note that the values of endpoints known to be affected by ozone that we are not able to monetize are assigned a placeholder value, e.g. B_1, B_2, etc. These values can be either positive or negative, depending on the effect of ozone reductions on the endpoint. For example, decreases in ozone may result in increased exposure to UV-b radiation, which reduces benefits. Unquantified physical effects are indicated by a U. The estimate of total benefits is thus the

sum of the monetized benefits and a constant, **B**, equal to the sum of the unmonetized benefits, $B_1+B_2+...+B_n$.

Table 3-2.
Quantified Endpoints and Studies Included in the Primary Analysis

Endpoint	Health Effects Study	Study Population
Chronic Asthma	McDonnell et al. (1999)	Non-asthmatics, 27 and older
Hospital Admissions -- All Respiratory	Multiple Studies	Multiple Studies
Hospital Admissions -- Dysrhythmias	Burnett, et al. (1999)	All ages
Asthma-Related ER Visits	Multiple Studies	Multiple Studies
Minor Restricted Activity Days / Any of 19 respiratory Symptoms	Multiple Studies	Multiple Studies
Lost Worker Productivity	Crocker and Horst (1981)	Outdoor agricultural workers
Reductions in Crop Yields	NCLAN, 1988	Corn, cotton, peanuts, sorghum, soybean, and winter wheat

Table 3-3.
Values Applied to Changes in Health and Welfare Endpoints

Health or Welfare Endpoint	Valuation Estimate (1997$)	Derivation of Estimates
Chronic Asthma	$31,000 per incident	Based on results reported in two studies (Blumenschein and Johannesson, 1998; O'Connor and Blomquist, 1997). Assumes a 5% discount rate and reflects adjustments for age distribution among adults (ages 27 and older) and projected life years remaining.
Hospital Admissions		
All Respiratory (ICD codes: 460-519)	variable — function of the analysis	The COI estimates are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total respiratory illnesses) reported in Elixhauser (1993).
All Cardiovascular (ICD codes: 390-429)	variable — function of the analysis	The COI estimates are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total cardiovascular illnesses) reported in Elixhauser (1993).
Asthma-Related ER Visits	$280 per visit	COI estimate based on data reported by Smith et al. (1997).
Restricted Activity Days and Lost Productivity		
Minor Restricted Activity Days (MRADs)	$47 per day	Median WTP estimate to avoid 1 MRRAD – minor respiratory restricted activity day -- from Tolley et al.(1986) .
Lost Worker Productivity	1.4% increase in income for a 10% decrease in ozone	Information reported in Crocker and Horst (1981) on the impacts of ozone exposure on the productivity of outdoor citrus workers. The study measured productivity impacts as the change in income associated with a change in ozone exposure, given as the elasticity of income with respect to ozone concentration (-0.1427)
Reductions in Crop Yields	Sum of changes in producer and consumer surplus	The economic value associated with spatially heterogeneous levels of yield loss for ozone-sensitive commodity crops is analyzed using the AGSIM© agricultural sector model (Taylor et al., 1993).

A comparison of the incidence columns to the monetary benefits columns reveals that there is not always a close correspondence between the number of incidences avoided for a given endpoint and the monetary value associated with that endpoint. This reflects the fact that many of the less severe health effects, while more common, are valued at a lower level than the more severe health effects. This is, in fact, consistent with economic theory, which suggests that the value of a health effect should increase with the impact on an individual's utility.

Total monetized ozone-related benefits in 2007 are estimated to be $170 million (1997$). Over half (62 percent) of the total ozone-related benefits are accounted for by welfare endpoints (commercial agriculture and worker productivity). Of the health-related benefits, acute respiratory symptoms (measured by MRAD and any of 19 acute respiratory symptoms) account

Table 3-4.
Estimated Annual Health Benefits Associated With Air Quality Changes Resulting from the Final Section 126 Rule in 2007 for the "Representative Year" Scenario

Endpoint	Avoided Incidence (cases/year)	Monetary Benefits (millions 1997$)
Health Effects[a]		
Chronic asthma[b]	371	$11
Hospital Admissions from Respiratory Causes	529	$6
Hospital Admissions from Dysrhythmias	136	$1
Emergency Room Visits for Asthma	165	$<1
Minor restricted activity days/Acute respiratory symptoms	1,021,874	$46
Decreased worker productivity	—	$95
Other ozone-related health effects	U_1	B_1
Welfare Effects		
Commercial Agricultural Benefits (6 major crops)	—	$11
Commercial Forestry Benefits	—	B_2
Other Ozone-related Welfare Effects	—	B_3
Total Monetized Ozone-related Benefits[c]	—	$170+**B**

[a] Premature mortality associated with ozone is not separately included in this analysis. It is assumed that the Pope, et al. C-R function for premature mortality captures both PM mortality benefits and any mortality benefits associated with other air pollutants (see Chapter 11 of the Section 126 RIA for a more complete discussion of measurement and valuation of air pollution related mortality.)
[b] While no causal mechanism has been identified linking new incidences of chronic asthma to ozone exposure, a recent epidemiological study shows a statistical association between long-term exposure to ozone and incidences of chronic asthma in some non-smoking men, but not in wormen.
[c] **B** is equal to the sum of all unmonetized categories, i.e. $B_1+B_2+...+B_9$.

for 72 percent and chronic asthma accounts for 17 percent.

In the Section 126 RIA, we projected ozone benefits of $230 million (1997$). Thus, our final estimate of ozone-related benefits indicates that the benefits transfer overstated ozone-related benefits by approximately 35 percent. However, combined benefits (PM and ozone) were projected to be $1.2 billion. The difference between the ozone benefits estimates of $60 million amounts to only 0.5 percent of the total combined estimate. This trivial difference does not alter the agency's conclusion

that the monetized benefits of this rule are substantial, and, as demonstrated in the next chapter, outweigh the monetized costs.

3.4 References

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